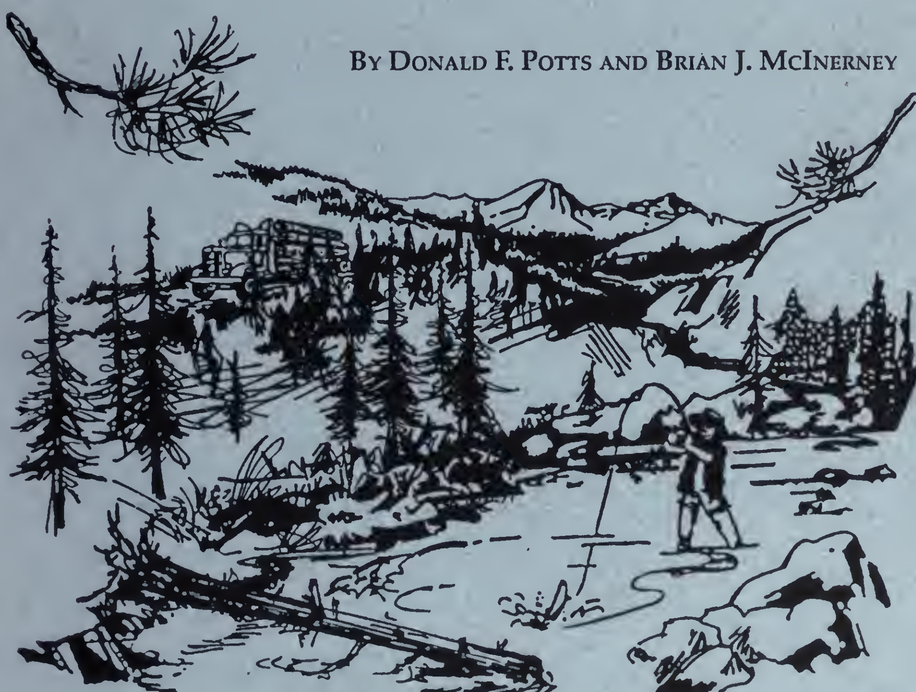
Flathead Basin Forest Practices
Water Quality and Fisheries
Cooperative Program

Application of the Sequoia Method for Determining Cumulative Watershed Effects in the Flathead Basin

By Donald F. Potts and Brian J. McInerney



June 1991

About This Report

This report is one of ten individual studies conducted for the Flathead Basin Forest Practices/ Water Quality and Fisheries Cooperative Program. The Cooperative Program was administered by a Coordinating Team representing the Montana Department of State Lands Forestry Division, the Flathead National Forest, Plum Creek Timber Company, L.P., the Montana Department of Fish, Wildlife and Parks, the Montana Department of Health and Environmental Sciences' Water Quality Bureau, the University of Montana, and the Flathead Basin Commission.

The Cooperative Program's specific objectives were (1) to document, evaluate, and monitor whether forest practices affect water quality and fisheries within the Flathead Basin, and (2) if detrimental impacts exist, to establish a process to utilize this information to develop criteria and administrative procedures for protecting water quality and fisheries.

The ten individual studies included the evaluation of: (1) specific practices at the site level, (2) accumulation of practices at the watershed level, (3) general stream conditions, (4) water quality variables relative to levels of management activity in small watersheds, (5) fish habitat and abundance relative to stream variables influenced by forest practices at the watershed level, (6) long-term changes in large-stream dynamics related to historical records of natural and man-related disturbances, and (7) changes in lake sediments relative to historical records of natural and man-related disturbances. A *Final Report* was developed which contains summaries of each of the studies, a set of summary conclusions and recommendations, and a formal response to the recommendations by the land management organizations which administered the Cooperative Program.

Contributors

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FLATHEAD BASIN WATER QUALITY

AND

FISHERIES COOPERATIVE

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APPLICATION OF THE SEQUOIA METHOD FOR DETERMINING CUMULATIVE WATERSHED EFFECTS IN THE FLATHEAD BASIN

FINAL REPORT

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June 1991

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EXECUTIVE SUMMARY

A cumulative watershed effects risk assessment procedure, representative of the U.S. Forest Service, Region 5 methodologies, has been applied to the entire Swan River watershed, and to 30 smaller Flathead Basin watersheds. The Swan and the 30 smaller watersheds were selected for study by the Flathead Basin Water Quality and Fisheries Cooperative because of their high fisheries values and growing concerns over possible or potential impacts from forest management.

The risk assessment procedure, SEQUOIA, was developed by the Sequoia National Forest in 1980, and is basically an accounting system for areal disturbance. Forest management activities are assigned a Runoff Coefficient that varies with their relative degrees of site compaction and soil exposure. The coefficients range from a high of 1.0 for permanent harvest system roads to a low of 0.1 for cable system partial cuts and low intensity (10% soil exposure) prescribed or wild fire. The Runoff Coefficient times the area disturbed is called the Cumulative Runoff Acreage (CRA, or in other Region 5 methods, the Equivalent Road Acreage). The model assumes disturbances from management activities are assumed to recover within 10 years. Roads, trails and recreation and administrative sites never recover.

The basic premise of SEQUOIA is that soil compaction and soil exposure effectively increase the drainage efficiency of a watershed, thus increasing the magnitude of peak flows, which in turn may cause destabilization of channels and deterioration of

fisheries and water quality. Based on research conducted in Oregon and California, the procedure recommends a Threshold of Concern (TOC) for watersheds with "average sensitivity" when the Cumulative Runoff Acreage reaches 12% of the watershed.

The Swan River watershed was partitioned into 54 analysis units ranging in size from roughly 1400 to over 23000 acres. The partitioning was based on a compartment layer on the Flathead National Forest MURIS. Many of these analysis units are not discrete watersheds, but are of sizes typical of third- to fifth-order drainage basins. All forest management activities during the past decade and all existing road information in each of the analysis units was obtained from the various land owners present. SEQUOIA estimates of areal disturbance ranged from a high of nearly 40% of an analysis unit to 0%. Thirteen of the analysis units had disturbance greater than SEQUOIA's 12% threshold of concern. Nearly 11% of the Swan River watershed received some sort of harvest treatment during the 1980's, conducted on over 750 miles of temporary or permanent roads, totalling (in 1989) a Cumulative Runoff Acreage of about 8% of the entire Swan watershed.

SEQUOIA was similarly applied to the 30 smaller watersheds located within the Flathead Basin. Cumulative Runoff Acreages in these critical fisheries ranged from 0% in Elk Creek and Lion Creek to over 30% in Freeland Creek. In addition to Freeland Creek, Cumulative Runoff Acreages in Jim Creek, Fish Creek and Sheppard Creek were above SEQUOIA's 12% threshold of concern.

The Squaw Creek tributary and Hand Creek are approaching the threshold.

The Flathead National Forest and the Montana Department of State Lands currently use similar water yield models, based on the Equivalent Clearcut Area (ECA) concept. Rather than measuring compaction and soil exposure in anticipation of changes in peak discharges, the ECA models measure canopy removal in anticipation of changes in average annual water yield. In the Flathead Basin, it is assumed that channels with "normal" stability can withstand an increase of 10% in annual water yield. The ECA and the CRA model predictions should be correlated - you can't remove canopy without soil compaction and exposure. Nevertheless, the models measure different impacts and have different underlying assumptions.

The ECA model was applied to the same 30 critical fisheries watersheds as SEQUOIA, and in the same rank order Freeland, Fish and Sheppard Creeks were judged to be above the threshold of concern. The ECA model did not, however, find Jim Creek, the Squaw Creek tributary or Hand Creek to be at or near the threshold. Hopefully, these results, when compared and correlated with the other Cooperative studies, will allow us to gain understanding of cumulative watershed effects in the Flathead Basin.

The report that follows was the main body of a Master of Science thesis written and successfully defended by Brian McInerney at the University of Montana, School of Forestry. As

with any task that involves accounting of large quantities of data, mistakes and errors of omission are possible. We hope we have found most of them, but any that remain are solely our responsibility.

INTRODUCTION

The National Environmental Policy Act of 1969 (Public Law 91-190) directed agencies to assess cumulative impacts of management activities on the environment. The Act requires that all Federal agencies prepare environmental impact statements on projects that may be detrimental to the environment. The Council on Environmental Quality (CEQ) mandated that such statements consider direct impacts and cumulative impacts or effects. The CEQ defined cumulative impacts as "the impact on the environment which results from the incremental impact of the action when added to other past, present, or reasonably foreseeable future actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time" (CEQ 1978).

Forest management has the potential to produce cumulative effects on a number of resources including air, soil and terrestrial fauna and flora. However, because of the great value and importance of water resources and aquatic ecosystems, most of our attention has been devoted to the detection and analysis of cumulative watershed effects.

Cumulative Watershed Effects (CWE's)

Cumulative watershed effects are the results of downslope and\or downstream interaction of runoff and sediment from two or more management activities that reduce the productive land base

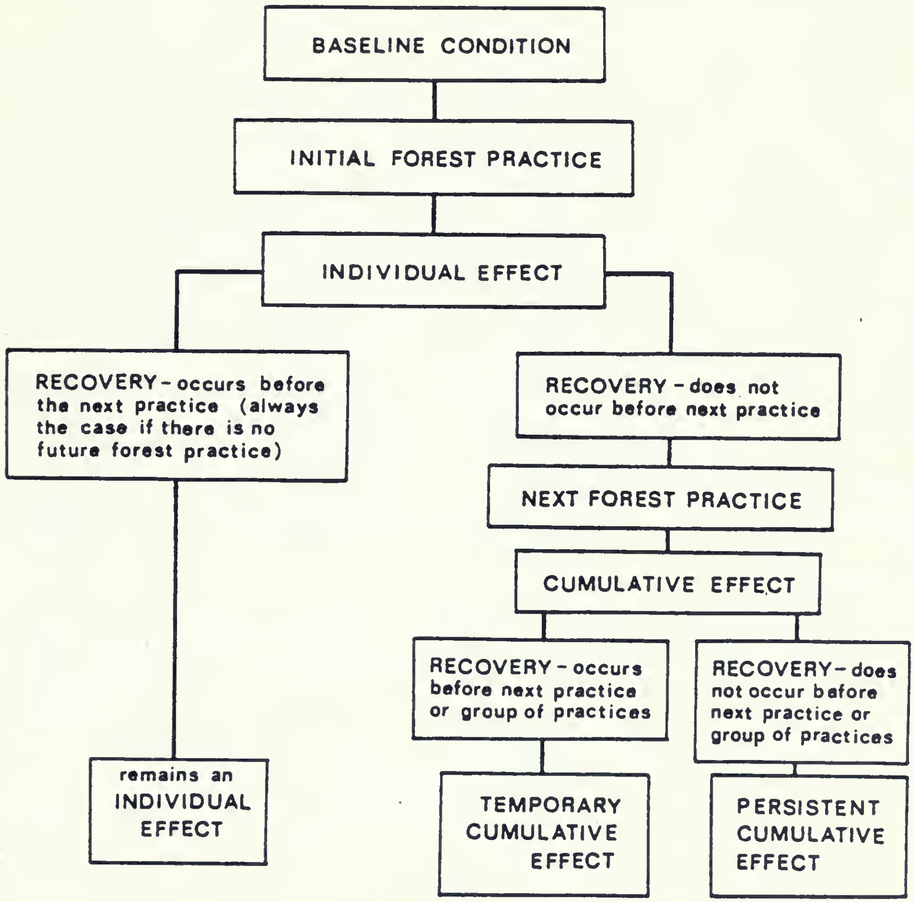

Figure 1. Pathways for the generation of cumulative watershed effects.

and impact aquatic resources. The USDA Forest Service (1988) defines cumulative watershed effects as any impact on beneficial uses of water that occur away from the locations of actual land use and which are transmitted through the fluvial system. Figure 1 shows the pathways for the generation of cumulative watershed effects.

A partial list of management related activities that increase surface runoff and sediment production includes road construction, silvicultural site preparation and release work, timber harvesting, prescribed fire, recreational vehicle use, and grazing. All these activities reduce vegetative cover and thereby decrease interception and evapotranspiration. Some of these activities also increase soil compaction and limit infiltration. The result is overland surface flows and increased peak flows in developed channels. This combination produces increased erosion and sedimentation that may in turn lead to degradation of aquatic ecosystems and a reduction in the quality of fisheries.

As indicated in figure 1, forest practices do not have to produce cumulative watershed effects. However, it is generally felt that certain factors are directly related to CWE's or produce a greater risk for their occurrence:

1) Concentration of activities in time and space
2) High road densities
3) Frequent rain-on-snow events
4) Mass failure (landslide) prone topography

5) Highly erodible soils

6) Low streambank stability

7) Past or present management activities occurring in ephemeral drainages

8) High rainfall intensities (greater than 5.5 inches per 24-hr. period)

Cumulative watershed effects may manifest themselves both on-site and off-site. On-site manifestations are typically physical evidence of watershed degradation and include gullies, rills and sheet erosion. Often these reduce the productive land base by removing fertile soil and lead to a reduction of the productive water base by degrading water quality (USDA Forest Service 1981).

Off-site manifestations of cumulative watershed effects may not be so obvious and may be difficult to link to upstream activity. The manifestations may include changes in channel geometry or channel pattern resulting from changes in sediment loads or magnitude or timing of snowmelt or storm runoff. These may produce larger and more frequent floods, worsening streamside mass-wasting, and other problems related to stream channel expansion.

Increasing peak flows in a stream has the same effect as decreasing the return period for major storm events. For example, what was formerly a 25-year flood might be expected to occur once every ten years. All the flooding, bank scour, sediment transport and erosive energy associated with larger storms happens with smaller, more frequent storms.

Mitigating or Preventing CWE's

Watershed scientists have long operated under the assumption that the best way to minimize the risk of CWE's is to distribute activities in space and time. This has recently been called the "dispersion paradigm" and criticized on the basis that there is little in the literature to support the notion that dispersion is effective. By the same token, however, there is little in the literature to support the contention that dispersion doesn't work.

Best Management Practices (BMP's) have been developed to control on-site increases in runoff and sediment production resulting from individual management activities. These practices, if implemented properly, usually keep erosion and sedimentation within acceptable limits. When the acceptable limits are exceeded, it is usually the result of two or more management activities interacting in ways not anticipated (Megahan 1974).

Cumulative effects may be mitigated by reducing sources of increased runoff and sediment. Paving or obliterating roads in effected watersheds are excellent, albeit expensive, examples. However, in watersheds with mixed-ownership, we will ultimately have to coordinate our management activities in order to mitigate cumulative effects. Some examples of this include shortening the time between harvest and regeneration and coordinating vegetation manipulation with the design and construction of the road system

to spread harvesting and planting activities out in time and space, and minimize road density.

Methods to Assess CWE's

Three basic methods are generally accepted for determining the presence and magnitude of cumulative watershed effects. The most conclusive of these methods is the actual measurement of changes or trends through monitoring. Monitoring, however, may be limited in effectiveness by both time and financial constraints.

A second accepted and widely practiced method for assessing CWE's is by auditing the application and effectiveness of on-site Best Management Practices (BMP's). The rationale is that BMP's are designed to minimize on-site impacts, thereby minimizing off-site impacts. Therefore, if BMP's are properly implemented, it is assumed that CWE's have been avoided.

The third accepted and widely practiced method for the assessment of CWE's is watershed modeling. This is the topic of this study and various modeling procedures will be discussed at length, subsequently.

Cumulative Effects in the Flathead Basin

One third of the Flathead Basin is composed of forested lands which are managed for timber production. The timber industry strongly supports the local economy, and contributes to the regional economic base. Flathead Lake and its tributary streams and rivers contain superior fish habitat and pristine

water quality that offers a different, though equally valuable economic and recreational resource.

Not until after the late 1940's and early 1950's were large tracts of timber cut from non-private forest lands. The rate of timber harvest in the Flathead Basin, specifically the Swan River watershed, has accelerated in recent years (see Figure 2). Continued harvesting and road building is encroaching into headwater drainages characterized by steep slopes and erodible soils. These headwater fisheries and channels may well be negatively impacted by changes in water yield and probable increases in sediment. Increased water and sediment passes through to lower-order channels and ultimately to the lakes in the Flathead Basin. Are cumulative watershed effects resulting from forest management present in the Flathead Basin?

One form of long-term monitoring that has been conducted at selected locations in the Flathead Basin, is the routine gaging of streamflow. Present knowledge of possible streamflow changes resulting from forest management are based primarily on experiments conducted in small catchments. The impacts of timber harvest and road construction in larger drainage basins has not been well-documented. Nevertheless, given the substantial acreage harvested in the Swan, particularly over the last fifteen years, one might expect to find measured changes in water yield.

One technique that has been used to detect changes in watershed behavior following disturbance (e.g. Potts 1984) is called the Double Mass Curve (Searcy and Hardison 1960).

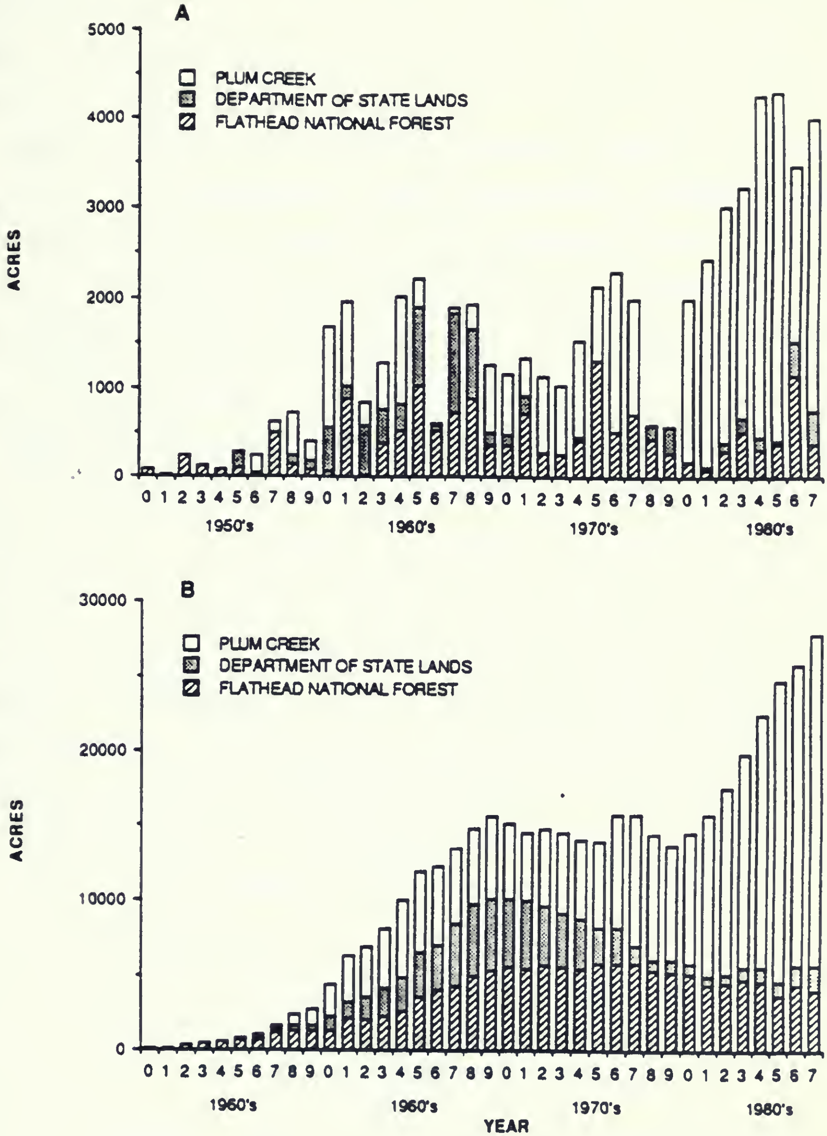

Figure 2. A) Total Equivalent Clearcut Acres (ECA) harvested each year, 1950-1987, in the Swan Watershed. B) Ten-year cumulative ECA harvested by landowner. From Hauer (1990).

Basically, the procedure looks for changes in the relationship of mass-accumulation, over time, at two or more stations. In the following example (see Figure 3), annual water yields in the Swan River are accumulated at Condon (USGS gage #12369200) and at Bigfork (USGS gage #12370000) during the period 1973 - 1989. The majority of timber harvest activity in the Swan has been between these two locations in the Swan watershed. An expected cumulative effect would be increased cumulative water yield at Bigfork relative to the cumulative water yield at Condon.

If there was an obvious change in the slope of the curve, which could be tested for significance using analysis of

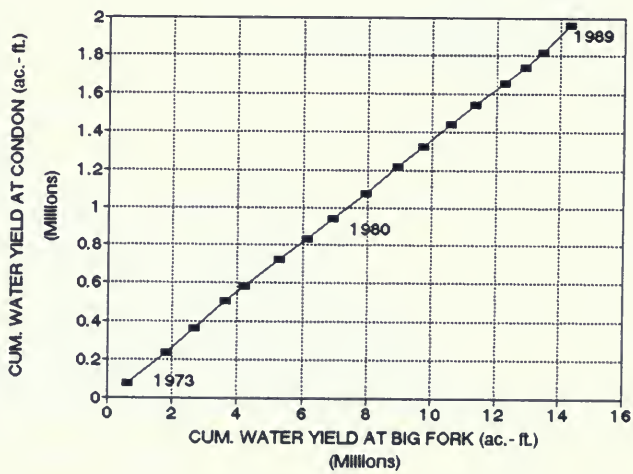

Figure 3. Double Mass Analysis in the Swan River, 1973-1989
USGS Stations at Condon and Bigfork

covariance, and which in this case should be a shift to the right, then the conclusion might be that cumulative effects have resulted from management activity.

Just because there is no apparent change in slope on the graph doesn't mean that cumulative effects aren't there. Annual water yield changes are only one possible cumulative effect, and our ability to measure water yield is only good to within perhaps 10% of the real value. The actual cumulative effect may be hidden by natural variation and within measurement error.

This is an example of the problems encountered while trying to show the presence of cumulative effects. Without a clear answer provided by a technique like the Double Mass Analysis, we're still left asking the question whether or not CWE's are present. To address these problems, the Flathead Basin Fisheries and Water Quality Cooperative was formed. The Cooperative represents a coordinated effort consisting of federal and state agencies and private industry.

The main goals of the Cooperative are to:

1. Determine the effects of forest practices on water quality.
2. Develop a process for protecting water quality from unacceptable impacts from forest practices.
3. Develop a monitoring program to supplement, if necessary, the monitoring program of the Flathead Basin Commission.
4. Identify and implement continuing, coordinated

research and evaluation as a follow-up to initial activities.

<u>Study Objectives</u>

The objective of this study is to help find a way for the Flathead Basin Fisheries and Water Quality Cooperative to answer questions concerning cumulative watershed effects and the relationship between forest management and water resources. We will apply a U.S. Forest Service Region 5 cumulative watershed effects risk assessment procedure, SEQUOIA, to the Swan River watershed and to 30 additional watersheds being studied by the Cooperative.

SEQUOIA's results on the 30 additional watersheds will be compared with the results of the water yield model currently used by the Flathead National Forest, using nonparametric rank correlation techniques. The purpose of the comparison is to assess the degree of association and correlation between the two models. This may improve confidence in the use of either or both models for assessing cumulative watershed effects in the Flathead Basin.

MODELING CUMULATIVE WATERSHED EFFECTS

Watershed modeling is a very broad subject, and the literature related to it is extensive. Basically, however, there are two different approaches to modeling CWE's: qualitative modeling or risk assessment, and quantitative modeling. Again, the literature is extensive, so only the qualitative and

quantitative methodologies developed or used in the northwestern United States will be discussed in this paper.

There are substantial differences between qualitative and quantitative approaches. Generally, qualitative approaches are used to estimate the risk or potential for watershed impacts using relative measures such as high, medium and low. They have been called non-argumentative procedures in that most professionals can agree on relative or order-of-magnitude impact scales. Quantitative methods usually involve process-type models inevitably containing empirically derived coefficients. The methods predict quantities of material produced - acre-feet of water or tons of sediment per square mile. Problems with quantitative methods center around acceptance of empirical coefficients, lack of model validation, and ultimately, interpretation. There are also hybrids of the two approaches which have fairly rigorous quantification of activities, yet are not related to measurable quantities of water or sediment.

<u>Quantitative Approaches</u>

Many forest hydrologists in the Northern Region (Region 1) use some form of the equivalent clearcut area (ECA) water yield model. The methodology is mainly used to forecast average streamflow responses to vegetation manipulation, road building, and fire. The ECA procedure was first published in "Forest Hydrology II: Hydrologic Effects of Vegetation Manipulation" (USDA Forest Service 1974) and has been critiqued in detail by Harr (1981) and King (1989).

Although many adaptations of the original method exist, the basic principles have not changed. The relationship between annual water precipitation and average annual water yield is used to estimate water yield after timber harvest operations. Following vegetation removal, the model predicts water yield increase by elevation zone and general aspect. Roads, clearcuts, burned areas, and partial cuts are all expressed as equivalent clearcut areas. There is also an option to use soil and land-type information to improve the elevation/water yield function. The ECA model also allows the user to estimate reductions in water yield increases as vegetation returns to its original state.

The Flathead National Forest routinely uses an adaptation of the ECA procedure called H2OY (USDA Forest Service 1979). H2OY was developed and programmed by the Idaho Panhandle National Forests and will be discussed in greater detail in the next section of this report.

The Environmental Protection Agency (EPA 1980) in cooperation with the U.S. Forest Service, designed an approach to evaluate nonpoint silvicultural sources of pollution known as WRENSS (Water Resources Evaluation Nonpoint Sources Silviculture). The handbook describes procedures to evaluate changes in water quality, quantity and timing due silvicultural activities.

Two water yield models were selected to fit the WRENSS requirements - The Subalpine Water Balance Model (WATBAL) (Leaf

and Brink 1973), and PROSPER (Goldstein and others 1974). WATBAL was designed to simulate management effects in snow-dominated hydrologic systems, PROSPER was designed for rain-dominated hydrologic systems. The models function similarly:

1) determination of on-site seasonal precipitation
2) determination of seasonal evapotranspiration
3) determination of determination of seasonal water yield, as the difference.
4) determination of changes in seasonal evapotranspiration caused by vegetation removal
5) determination of changes in seasonal water yield

Both models are very broad and intended to be used in varying climatic regions. A considerable amount of validation of the models has taken place, and there is growing confidence in their use.

The R1-R4 Sediment yield model (Cline et al. 1981) was developed for use in the northern Rocky Mountains, and utilizes major pieces of WRENSS hydrology in its procedure. R1-R4 is a "conceptual framework which outlines a process and is designed to be supplemented by local data". Its limitations and assumptions are clearly documented. Validation has proven difficult, however, so the model can and should only be used to compare various management alternatives.

The Montana Cumulative Effects Cooperative formally adopted (MCEC 1988) a computer model, WATSED, which combines a version of the ECA water yield model with the R1-R4 sediment model to

quantitatively model watershed impacts. The water yield component of WATSED is essentially the same as the Flathead National Forest's H2OY. The Cumulative Effects Cooperative is attempting to fine-tune the model using coefficients that reflect local conditions. The implementation of the model by Cooperators will not take place until required input data and coefficients are available to all participants. The intent is to provide a single, uniform model, and a common data base for all members of the Cooperative.

Qualitative Approaches

Musgrave (1947) was among the first to qualitatively approximate the relationships among management activities and erosion using four primary factors that influence erosion rates - rainfall, slope, soil type, and vegetative cover. He assigned a coefficient to the relative amounts of erosion observed under different vegetal covers which allowed a comparison of different vegetation conditions. Musgrave found that his work gave satisfactory results in many applications. However, the quantitative evaluation of the factors was limited by a lack of supporting research.

Leopold and others (1968) developed a procedure that assisted with the development of uniform environmental impact statements. They devised a matrix system for use in the preparation of environmental impact statements, which may also be used to evaluate impacts in watersheds. The procedure characterized the existing environment and included a detailed

description of environmental factors and the anticipated impacts of specific management activities. Leopold found the best utility of the matrix is its use as a checklist of the full range of impacts of management activities. However, the matrix should be prepared or reviewed by knowledgeable professionals to overcome subjectivity in rating the impacts of management activities.

Rickert (1975) felt that quantitative models must be based on sound data and reliable assumptions, but water quality problems may be too complex to model in a practical and useful manner. He therefore advocated the use of qualitative approaches.

Brown III and others (1979) developed a procedure based on Rickert's (1975) work and relationships among physiographic factors, land use activities, and the resulting erosional-depositional problems. Their study dealt with the Willamette River basin in Oregon, and their qualitative approach involved the development of an erosion-hazard land base map, accompanied by a Leopold-type matrix for rating erosional impacts. Erosional and depositional features, and land use activities were mapped using infra-red aerial photographs. The map and matrix were used to estimate erosion impact risk associated with forest management activities.

Rickert and others (1979) adapted the same procedure for assessing the impacts of land management activities on erosion-related nonpoint source identification and control in the Oregon

208 Nonpoint Source Assessment Project. The procedure relates stream quality conditions to regional terrain aspects and to forest management practices, and was expanded from the earlier method by utilizing ratings of stream quality and fish habitat. The Leopold-type risk matrix was also changed from order-of-magnitude to high-medium-low risk categories. Topographic features are related to stream quality ratings in a matrix format, to identify sensitive areas which may be the location of management activity. The combined information produces an interpretive map to locate management-sensitive areas.

Around 1980, a number of National Forests in Region 5 (California) developed similar qualitative cumulative watershed effects analyses, each with innovative analytical techniques for the diverse geomorphic provinces of the region (Rice 1982). The Shasta-Trinity National Forest staff designed one of these cumulative watershed effects models to address both Forest and project level needs. Haskins (1986), described the project-level application of the model. Forest-level planning is on a broader scale than project-level and is not discussed in his paper.

The Shasta-Trinity model is based on the assumptions that cumulative watershed effects are due in part to:

1) The amount of sensitive ground and its relative (high, medium, low) risk level within a watershed.
2) The timing and intensity of management practices within a watershed that can influence peak flows, erosion and sedimentation.

3) The proximity of management practices to sensitive areas.

The amount of sensitive ground is quantified empirically based on a watershed's physical characteristics. The age, area and intensity of management practices are compiled using the Equivalent Road Area (ERA) accounting system. It should be noted that the ERA is equivalent to the Cumulative Runoff Acreage (CRA) used in some other Region 5 procedures, and the two terms are used interchangeably. A third factor, the "threshold of concern" (TOC), represents the total ERA in a watershed beyond which it is believed that cumulative effects will be initiated.

TOC's combine management activities and sensitivity levels in a watershed. Haskins (1986) stated that "it is apparent that a watershed having a low sensitivity can withstand a higher level of management activity without incurring impact, than can a high-sensitivity watershed." Based on Harr and others (1975), and observations made on the Shasta-Trinity National Forest relating accelerated channel degradation to ERA, a 14% ERA was chosen as the TOC for the most sensitive watersheds, 16% for moderately, and 18% for the least sensitive watersheds.

The model is applied only to watersheds between 250 acres and 2000 acres. Haskins (1986) thought it important to maintain resolution within a watershed. If the watershed is too large, the activities will appear clumped together and will not show up in the analysis.

The Shasta-Trinity model has been used primarily as an alternative selection process to disperse timber harvest activities in time and space. It is also used to weigh economic losses against resource gains if timber sales are deferred.

The Sequoia National Forest (USDA Forest Service 1981), developed a similar methodology, known as the Sequoia Method (SEQUOIA), to analyze watershed disturbance. The Sequoia Method estimates watershed impacts with the ERA/CRA accounting system, but assigns 12% threshold of concern for most channels. A detailed description of SEQUOIA is presented in the next section of this report.

The Shasta-Trinity model and SEQUOIA are similar in analysis approaches. However, the Shasta-Trinity model is more site-specific and was meant to analyze smaller watersheds than SEQUOIA. The Shasta-Trinity model analyzes watersheds 25 to 2000 acres, while the authors of SEQUOIA thought it would function best on watersheds of between 5000 and 15000 acres.

Klock (1984) thought the most appropriate approach to determine the cumulative effects of forest practices on the downstream aquatic ecosystem would be a large watershed study - much like the one undertaken in the Flathead Basin. However, he observed that financial resources to sponsor large watershed studies are, and will remain, scarce.

Klock's alternative approach is a model, the Klock Watershed Cumulative Effects Analysis (KWCEA) that incorporates many of the analysis features of previous approaches. Although the model can

be used on large watersheds, it is best suited for watersheds up to 4000 hectares (about 10000 acres).

KWCEA calculates a single numerical value that is a linear function of a number of site-specific variables that include precipitation erosivity, surface erodibility, slope stability, hydrologic risk, topography, area of the activities, and the total area of the watershed. The equation is initially used to calculate a "reference year" or the existing condition, and then the effects of future management practices are calculated.

KWCEA values greater than 1.0 indicate potential for impacts on a watershed resulting from management activities. KWCEA values less than 1.0 indicate the potential for cumulative watershed effects are no greater than may be expected by natural hydrologic events. Klock believes the KWCEA model is useful for evaluating all planning options to estimate potential downstream impacts.

Grant (1986, 1988) proposed the use of aerial photographs to evaluate the presence of CWE's. Grant felt that previous studies dealing with cumulative watershed effects assumed links between upstream activities and downstream channel changes, but did not describe the importance of specific water and sediment delivery mechanisms.

Grant's model distinguishes different supply mechanisms, such as peak flows, chronic sediment input, and pulse sediment input, because each mechanism results in different channel responses. The most common response is a widening of channel

dimensions. Secondary responses include debris dam instability, accumulation of fines, and collection of assorted debris in the channel.

Grant felt that his technique uses parameters that can be rapidly (thus called RAPID) and inexpensively measured on aerial photographs as opposed to requiring detailed field observations, and therefore can be used in situations where other data are not available or where time and budgetary constraints do not allow a detailed field survey.

In 1988, the Forest Service's Region 5 formally directed the California Forests to develop their individual cumulative watershed effects methods, based on the generic "Cumulative Off-Site Watershed Effects Analysis" (USDA Forest Service 1988). Central to the procedure is the ERA/CRA accounting process.

Cobourn (1989a) described the most recent application of the now-official Region 5 cumulative effects analysis on the Eldorado National Forest. There the analysis is a four-phased process that, 1) evaluates the natural sensitivity watersheds, 2) develops a land disturbance history, 3) field-surveys the watershed, and 4) estimates the threshold of concern (TOC).

Cobourn (1989b) found that these Region 5 cumulative watershed effects analyses are now workable, but they need further refinement and validation before critics will be satisfied. He thinks the analyses should be used in a monitoring system that enables long-term tracking, and that

higher water quality will result from coordinated, long-range planning to guard against cumulative watershed effects.

Hogan and others (1989) designed a sediment transfer hazard classification system. The system is based on geomorphic factors that influence sediment production, transport, and deposition. Aerial photographs, topographic maps, fish habitat inventories and interpretive terrain maps are used to describe the factors involved. The data are input into a sediment transfer hazard map which is used to indicate where sediment production and transfer will affect key fisheries areas. Hogan and others found this is an effective way to restrict forest harvesting or focus limited funds on special road and harvest techniques.

McCorison and others (1989) developed a method to analyze watershed sensitivity on the Tongass National Forest. The Tongass needed a system that could indicate how much harvest watersheds could absorb over short time intervals without incurring unacceptable levels of cumulative watershed effects.

To accomplish this they modified the "Watershed Sensitivity" model, which is an ARC\INFO Geographical Information System (GIS) application. They used four subjective index values that could be rated by the watershed personnel - extreme, high, moderate, and low sensitivity. The model has a parallel procedure for evaluating flow regime changes.

CHOOSING A QUALITATIVE CWE MODEL FOR MONTANA

The Sequoia Method to predict cumulative watershed effects was chosen for use in this study for a variety of reasons.

First, and foremost, was that it is representative of the Region 5 methodologies. In short, we are not "re-inventing the wheel", but simply applying a model that was developed elsewhere and is currently in use. Further, to analyze very large watersheds, time constraints alone make it important to use methods not requiring detailed site-specific data.

In a preliminary study, SEQUOIA was compared to KWCEA (Klock 1985), OREGON (Rickert, et al. 1979), and RAPID (Grant 1986, 1988) to assess input data requirements, ease of application and ease of interpretation. KWCEA requires far too much site specific information - obtaining all of the input data for the Flathead Basin would be impossible. OREGON input data requirements are more reasonable, but the outputs are map products, and do not directly meet the requirements of this study. The OREGON method was adopted for a Geographic Information System (GIS) application, however (Lull 1990). RAPID looks for channel changes using aerial photogrammetry. The method requires a historical series of air photos and then can be used only on larger rivers and streams. We don't have the necessary photogrammetry and we have many concerns about smaller bodies of water. SEQUOIA offers a compromise in data requirements and utility. Further, the Sequoia National Forest may be more like western Montana than any other Region 5 Forest. Thus, derived coefficients that may be influenced by climate, for example, may be more reliable.

SEQUOIA

SEQUOIA estimates watershed impacts based on Cumulative Runoff Acreage (CRA, which is the same as Equivalent Road Area, ERA), which is a measure of aerial disturbance (compaction, primarily) in a watershed. CRA considers roads and skid trail systems, types of harvest activity and site preparation, and ages of the various treatments. The rationale behind the model is that compaction of soil reduces storage and provides an effective increase in the drainage density of a watershed. The result of these two impacts are usually an increase in water yield and a tendency towards higher peak flows. The Sequoia National Forest assumes that a 12% CRA is a "threshold for concern" for the majority of their stream channels and indicates when cumulative watershed effects resulting from changes in runoff quantity and timing may occur.

Table 1 displays Runoff Coefficients (RC's) and Recovery Rates for various practices, as they are used in the model. Runoff coefficients are scaled relative to system roads that have an RC of 1.0. RC's are highest in the first year following disturbance and with the exception of roads, recreation areas and administrative sites, disturbances recover within 10 years. Interestingly, a 10 year recovery together with roads, in a watershed with a 12% threshold, would produce a watershed rotation of about 120 years. This is rotation age for many commercial species in the Flathead.

The calculation to determine a CRA for a specific activity is straight-forward and simple:

CRA = Equivalent Acres (EA) X Runoff Coefficient (RC)

Equivalent Acres are the actual number of acres harvested or treated for silvicultural activities. EA's for system roads, abandoned roads and ORV trails are figured at 3.5 acres, 2 acres, and 1.5 acres per mile, respectively. Permanent skid systems and landings are figured at 27% of the harvested acres. Table 2

Table 1. Runoff Coefficients and Recovery Rates

	YEARS										
ACTIVITY	0	1	2	3	4	5	6	7	8	9	10
Tractor Clearcut	.4	.4	.35	.2	.1	.1	.1	.1	.1	.1	.1
Cable Clearcut	.2	.2	.2	.15	.1	.1	.1	.1	.1	.1	.1
Tractor Partial	.2	.2	.15	.1	.1	.1	.1	.1	.1	.1	.1
Cable Partial	.1	.1	.1	.1	0	-	-	-	-	-	-
Site Prep Mech.	.7	.7	.6	.5	.3	.2	.1	.1	.1	.1	.1
Mechan. Release	.5	.4	.4	.3	.25	.15	.1	.1	0	-	-
Aband. Roads	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9
Perm. skid sys.	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9
Burns 10% soil	.1	.1	.1	0	-	-	-	-	-	-	-
Burns 80% soil	.4	.4	.35	.3	.2	.1	0	-	-	-	-
ORV Trails	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9
System Roads	1	1	1	1	1	1	1	1	1	1	1

Table 2. Extent of Activities - Equivalent Acres

Activity	Equivalent Acres
Tractor Clearcut	Harvested Acres
Cable Clearcut	Harvested Acres
Tractor Partial-cut	Harvested Acres
Cable Partial-cut	Harvested Acres
Mechanical Site Prep.	Treated Acres
Mechanical Release	Treated Acres
Abandoned Roads	Miles X 2 Acres
Rec. & Admin. Sites	Acres of Sites
Perm. Skid System/landings	Harvested Acres X 27%
Burns	Acres Burned
ORV Trails	Miles X 1.5 Acres
System Roads	Miles X 3.5 Acres

shows the EA's for various activities. The total CRA for a watershed is simply the sum of the CRA's for all activities.

A Test of SEQUOIA

Before committing to all the work necessary to build the data base to run SEQUOIA in the Flathead Basin, a feasibility study was conducted on the Howard Creek watershed on the Lolo National Forest. Howard Creek (see Figure 4) totals 12636 acres, is a classic example of mixed-ownership, and currently is under a timber harvest-moratorium on Forest Service land because watershed monitoring indicated the onset of cumulative effects. There has been a considerable amount of logging and road building in the watershed. Recreational use may also impact peak flows and sediment production.

Timber harvest activities during the past ten years and road data for Howard Creek were solicited from Champion Timber Lands, Plum Creek Timber and the Lolo National Forest. Dozer piling and burning were the standard site preparation techniques used in the

watershed, but in some cases, site preparation had not been completed.

The detailed results of the SEQUOIA application in Howard Creek are presented in the next section of this report, but as of Fall 1989, the watershed had over 78 miles of system roads and over 2700 acres that had received some type of silvicultural treatment during the 10 previous years.

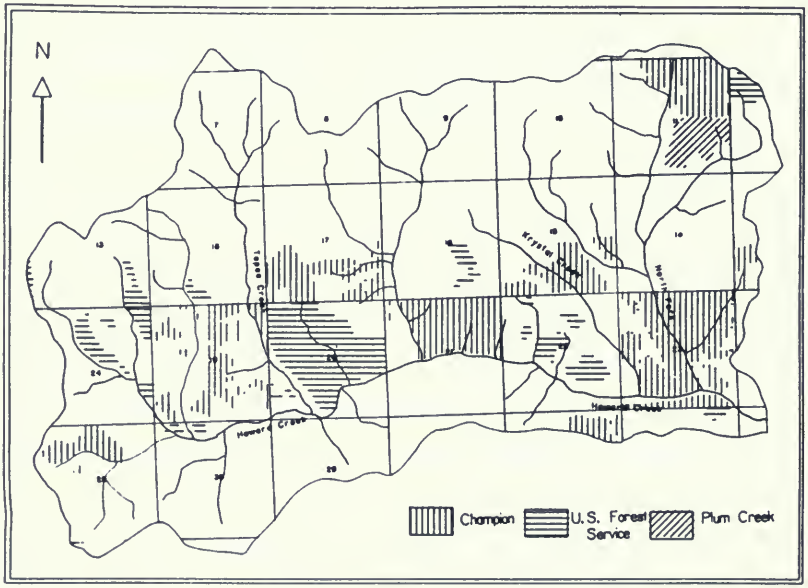

Figure 4. A Map of Howard Creek on the Lolo National Forest, Showing Harvested Areas, by Ownership

<u>The Use of SEQUOIA in the Flathead Basin</u>

A compartment boundary information layer on the Flathead National Forest MURIS system was used to partition the Swan River

watershed into 54 analysis units (Figure 5). Some analysis units do not have topographic divides for boundaries, and analysis units range from 2663 to 14978 acres (Figure 6). Two analysis units (#29, #32) are larger than others because they hold large tracts of roadless, unmanaged land. These analysis units were chosen, rather than actual watersheds, because they were more uniform in size, and because topographic boundaries on the broad, flat bottom of the Swan valley are ill-defined. Most of the upland analysis unit boundaries coincide with actual watershed boundaries.

The areal extent of all forest management activities for the past ten years was accounted for in each analysis unit. Activity records were obtained from the Flathead National Forest, Montana Department of State Lands, and Plum Creek Timber Company. Harvest methods, acreage, and year of harvest were recorded. Site preparation information was provided by the respective land managers.

SEQUOIA weights impacts from abandoned roads and system roads differently. However, because maps obtained from the land owners didn't always make a distinction between those roads, we assumed that all roads within sale areas were abandoned and that all connecting roads outside of the cutting units were system roads. Skid trail systems and landings were assumed to total 27% of the harvested acres in each unit. This value may be high, but was the default value suggested in the SEQUOIA documentation.

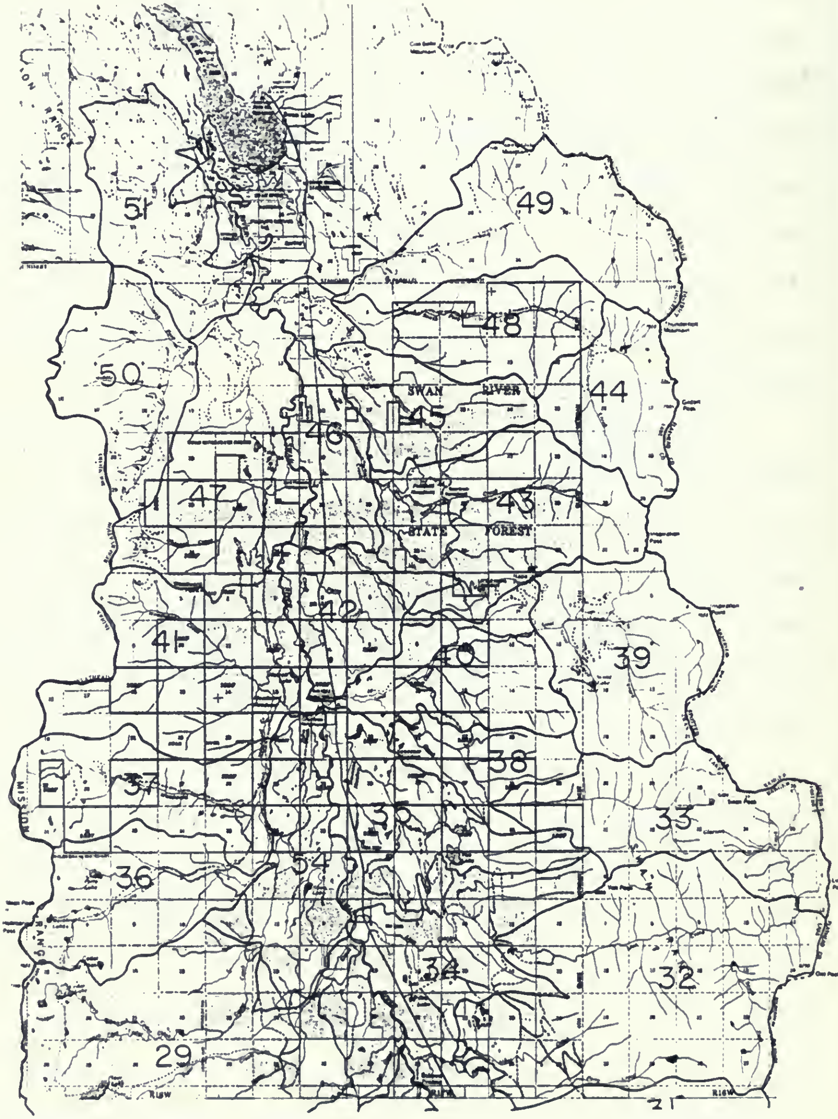

Figure 5A: The Swan Watershed Analysis Units — North

Figure 5B. The Swan Watershed Analysis Units — South.

Analysis unit boundaries, harvest unit boundaries and all roads were drawn onto 1:24000 scale US Geological Survey maps for subsequent analysis. All road lengths and boundary perimeters and areas were measured with a LASICO Model 1280 Digitizer/ Planimeter.

SEQUOIA was also applied to 22 additional <u>watersheds</u> in the Flathead National Forest, and 8 <u>watersheds</u> (not analysis units) in the Swan River Drainage. The 30 additional watersheds were chosen because of their importance as fisheries and they are being intensively studied in other projects funded by the by the Flathead Cooperative.

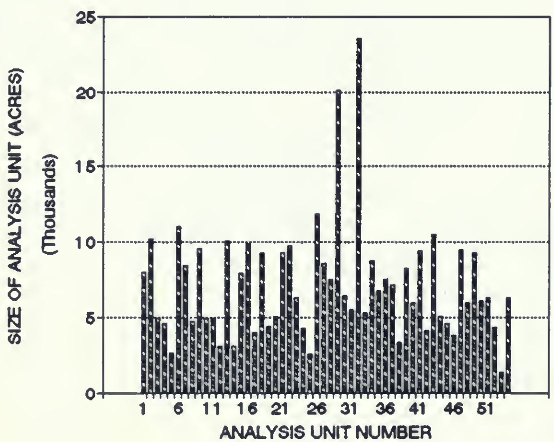

Figure 6. Size Distribution of the Swan Analysis Units

The Water Yield Model, H2OY

The water yield analysis model, H2OY (USDA Forest Service 1977), is an adaptation of the Equivalent Clearcut Area (ECA) procedure that was developed by the Idaho Panhandle National Forests then adopted and currently used by the Flathead National Forest. The procedure estimates the effects of timber harvest, fires and roads on streamflow.

The ECA procedure is basically a two step method:

1) Average annual water yields at different elevations for undisturbed forest conditions are estimated. Average annual water yield for the watershed is determined by summing the area-weighted yield from each elevation zone.

2) Increases in average annual water yield, by elevation zone, following vegetation removal are estimated. Roads, clearcuts, burned areas, and partial cuts are all expressed as "equivalent clearcut areas".

In the ECA procedure, the increase in annual water yield is distributed by months over the snowmelt season as a function of general aspect and elevation of the equivalent clearcut areas. This distribution of water yield is done to allow estimation of increases in the highest monthly yield and the channel impact period.

To reflect local and regional conditions, the model documentation recommends three timber harvest guidelines:

1) limitation of increases in average annual water yield to 10 percent, which may be adjusted depending on channel stability or soil characteristics.

2) limitation of increases in the highest monthly yield to 20 percent.

3) limitation of increases in the channel impact period to 20 percent.

These guidelines are based on local analysis of runoff, topography, and channel conditions. It is assumed that most third- to fifth-order drainages can sustain a 5 to 17 percent runoff increase as a result of timber harvest and road building.

Water yield increases recover to original yields with time. The Flathead National Forest uses log-linear recovery curves, based on forest habitat types. Unlike the 10-year disturbance recovery rates used in SEQUOIA, hydrologic recovery rates used in H2OY range from 60 to 120 years.

<u>Comparison of SEQUOIA and H2OY</u>

SEQUOIA and H2OY both measure disturbance, but they measure different parameters, operate under different assumptions, and use vastly different recovery rates following disturbance. Nevertheless, since canopy removal can only be facilitated by road access and ground disturbance, there should be a reasonable correlation between the estimates made by the two models.

Parametric statistics depend on a variety of assumptions dealing with populations, most notably equal variances and normal

distributions. Nonparametric methods are distribution free, and lend themselves to comparisons like the one presented.

Pearson's R nonparametric correlation was used in this comparison. Pearson's R is a measure of association indicating the strength of the linear relationship between two variables. The interpretation of R is the same as for the parametric correlation coefficient, r. If R is close to 0, little or no association between the variables is present. If the value of R approaches +1.0 or -1.0, strong association is present.

This comparison is specifically testing the correlation between the disturbance ranking of the same 30 watersheds as determined by two different methods. The 95% confidence interval for the significant value of R with a sample size of 30 lies between 0.755 and 0.945.

RESULTS

Howard Creek

Table 3 displays the accounting of activities and disturbances which taken place in Howard Creek during the past 10 years.

Table 3. Determination of Cumulative Runoff Acres for Howard Creek, Montana.

The following definitions apply in this table:
TPC = Tractor logged, partial cut
TCC = Tractor logged, clearcut
CPC = Cable logged, partial cut
CCC = Cable logged, clearcut
SPD = Site preparation, dozer piling
SPB = Site preparation, burning

Table 3. (continued)

Sale #	Activity	Age (yrs)	EA	* RC	= CRA
1	TPC	3	110	0.10	11.00
2	CPC	9	84	0.00	0.00
	*SPD	9	84	0.09	7.56
3	TPC	9	28	0.10	2.80
4	TPC	9	64	0.10	6.40
	*SPD	9	64	0.09	5.76
5	TPC	10	51	0.00	0.00
	*SPD	10	51	0.00	0.00
6	TPC	3	84	0.10	8.40
7	TPC	3	108	0.10	10.80
8	TPC	3	31	0.10	3.10
9	TPC	3	134	0.10	13.40
	*SPB	4	134	0.00	0.00
10	CPC	4	97	0.00	0.00
11	TPC	4	38	0.10	3.80
	*SPD	4	34.2	0.30	10.26
12	TPC	4	163	0.10	16.30
	*SPD	4	146	0.30	44.01
13	TPC	4	193	0.10	19.30
	*SPD	4	173.7	0.30	51.90
14	TPC	7	12	0.00	0.00
15	TPC	7	89	0.10	8.90
16	TPC	7	45	0.10	4.50
17	TPC	7	98	0.10	9.80
18	TPC	7	52	0.10	5.20
	*SPD	7	46.8	0.10	4.70
19	TPC	8	27	0.10	2.70
20	TCC	8	25	0.10	2.50
21	TCC	8	6	0.10	.60
22	TCC	8	10	0.10	1.00
	*SPD	8	16	0.10	1.60
23	TCC	8	4	0.10	.40
24	TPC	5	35	0.10	3.50
	*SPB	5	35	0.00	0.00
25	TPC	5	33	0.10	3.30
	*SPD	5	29.7	0.10	5.94
26	CCC	5	38	0.10	3.80
	*SPB	5	38	0.00	0.00
27	*CPC	5	47	0.00	0.00
	*SPB	5	47	0.00	0.00
28	TPC	5	63	0.10	6.30
	*SPD	5	56.7	0.20	11.34
29	CPC	5	4	0.00	0.00
	*SPD	5	3.6	0.20	.72
30	CPC	5	63	0.10	6.30
	*SPD	5	56.7	0.20	11.34
31	CPC	5	40	0.10	4.00
	*SPD	5	36	0.20	7.20

Table 3. (continued)

32	TPC	5	6	0.10	0.60
	*SPB	5	6	0.00	0.00
33	TCC	5	4	0.10	0.40
	*SPD	5	3.6	0.20	.72
34	CPC	5	3	0.00	0.00
	*SPD	5	27	0.20	.54
35	TPC	5	19	0.10	1.90
	*SPD	5	17.1	0.20	3.42
36	TPC	5	59.4	0.20	11.88
	*SPD	5	59.4	0.20	11.88
37	TPC	5	85	0.10	8.10
	*SPD	5	76.5	0.00	0.00
38	CPC	5	23	0.00	0.00
39	TPC	5	48	0.10	4.80
40	TPC	5	43.2	0.20	4.80
	*SPD	5	14	0.10	1.40
41	TPC	5	12.6	0.20	2.52
42	TPC	5	8	0.10	.80
	*SPD	5	7.2	0.20	1.44
43	TPC	5	18	0.10	1.80
	*SPD	5	16.2	0.20	3.24
44	TPC	3	110	0.10	11.00
45	TPC	4	30	0.10	3.00
46	CPC	4	8	0.00	0.00
47	TPC	4	38.6	0.00	0.00
				TOTAL	389.39

TOTAL OF ALL SYSTEM ROADS, ORV ROADS, AND TRAILS:

	TOTAL MI.	x	RC	=	EQUIVALENT ACRES
System Roads	78.2		3.5	=	273.7
ORV Roads	27.7		1.5	=	41.5
Trails	25.5		1.5	=	38.3
				TOTAL	353.5

TOTAL OF PERMANENT SKID SYSTEMS AND LANDINGS

harvested acres x 27% = equivalent acres for permanent skid systems and landings.

2701.9 x .27 = 729.5 equivalent acres

TOTAL CRA

	CRA
harvested acres	389.4
system roads (273.7 X 1)	273.7
ORV roads & trails (79.8 X .9)	71.8
permanent skid systems and landings (729.5 X .9)	656.6
TOTAL	1391.5 CRA

Swan River Analysis Units

Similar accounting of all forest management activities in the 54 Swan River analysis units appears in Appendix 1. Table 4 ranks the 54 Swan River analysis units from highest to lowest percentage of unit disturbance. The units ranged from 40.9% of disturbance in unit #24, to 0% disturbance in nine other units.

Table 4. Swan River Analysis Units Ranked by % of Disturbance

AU	AREA (ACRES)	HARVEST (ACRES)	ROADS (MILES)	CRA (ACRES)	DISTURBANCE (% of AU)
24	4315.9	2007.0	28.9	1768.2	40.9
54	6267.5	1884.0	21.7	1764.2	28.2
35	6730.9	253.0	17.2	179.9	27.0
26	11845.7	4429.0	69.8	2985.7	25.2
28	7529.8	3182.0	21.1	1708.1	22.7
12	3122.1	709.2	13.4	636.7	20.3
40	5968.6	1684.0	12.5	1202.5	20.1
38	3397.6	1049.0	13.5	611.1	18.0
30	6427.9	1780.0	22.0	1040.7	16.2
42	4182.1	1395.0	13.4	620.5	14.8
53	1401.2	158.0	8.2	177.9	12.6
8	4775.0	831.0	23.5	595.8	12.5
27	8594.3	2052.0	13.8	1052.6	12.2
47	9489.7	1734.5	29.3	825.9	10.8
41	9429.3	1548.0	5.6	971.7	10.3
46	3817.4	1027.0	12.5	394.2	10.3
25	2592.4	714.0	24.9	262.1	10.1
23	6336.1	484.0	18.3	584.3	9.2
4	4591.4	627.0	21.2	359.2	8.7
29	20067.2	2618.0	35.0	1730.6	8.6
52	4380.7	504.0	18.2	353.9	8.1
18	9274.5	1173.0	27.5	698.3	7.5
19	4407.7	876.0	14.1	330.5	7.5
31	5509.6	578.0	11.8	404.6	7.3
11	4946.3	390.0	16.6	348.8	7.0
10	4958.7	456.0	13.8	335.6	6.8
37	7162.5	754.0	8.2	468.7	6.5
13	10009.1	902.0	11.7	628.7	6.3
34	8776.8	959.0	26.4	512.5	5.8
51	6336.1	1032.0	12.1	337.0	5.3
45	4591.4	180.8	10.9	238.7	5.2
50	6152.4	585.0	10.2	304.1	4.9
3	4958.7	177.0	9.4	207.1	4.2
20	5050.4	226.0	8.5	203.7	4.0

Table 4. (continued)

21	9274.5	1047.5	22.7	307.8	3.3
7	8448.1	613.0	20.2	261.6	3.0
6	11019.2	1054.0	16.7	278.6	2.5
39	8264.4	432.0	19.6	190.6	2.3
43	10468.3	516.9	5.8	214.6	2.0
32	23507.7	658.0	9.2	444.2	1.9
9	9550.0	225.0	9.3	162.1	1.7
49	9274.5	182.0	10.2	68.3	0.7
22	9733.7	88.0	2.3	48.4	0.5
48	5968.8	121.0	1.1	21.5	0.4
36	7529.8	18.0	3.6	21.5	0.2
1	7988.9	0.0	0.0	0.0	0.0
2	10192.8	0.0	0.0	0.0	0.0
14	3122.1	0.0	0.0	0.0	0.0
33	5325.9	0.0	0.0	0.0	0.0
17	4040.4	0.0	0.0	0.0	0.0
5	2663.0	9.0	3.7	10.1	0.0
15	7897.1	0.0	0.0	0.0	0.0
16	9917.3	38.0	1.9	9.7	0.0
44	5050.4	0.0	2.1	0.0	0.0
TOTALS	386633.9	43960.9	753.6	26883.1	8.2

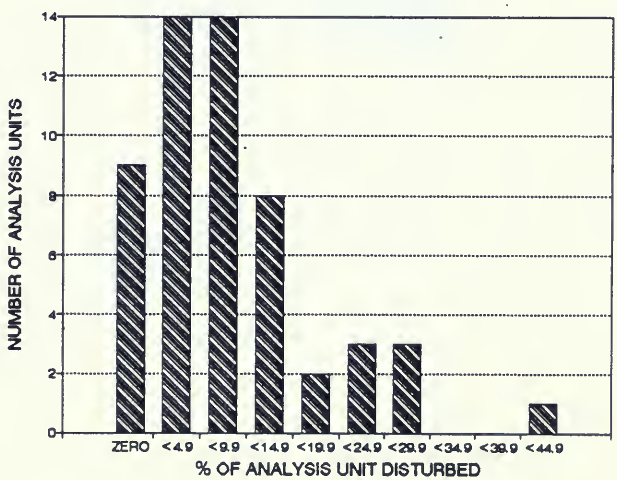

Figure 7. The Frequency Distribution of Analysis Unit Disturbance

Figure 8. Swan Analysis Units with Greater Than 12% CRA

Of the 54 analysis units evaluated, 13, or 24%, had CRA's 12% of the unit or greater. Seventeen analysis units, or 31%, had CRA's 10% of the unit or greater. The total cumulative runoff acreage in the Swan River watershed is 8.2% of the total land area. A frequency distribution of the percentage of analysis unit disturbance is shown in Figure 7. Those analysis units, shown in Figure 8, that are shaded black indicate disturbance levels greater than 12%. Note that the most heavily impacted analysis units seem to be concentrated or clumped together, rather than distributed across the watershed.

The 30 Flathead Basin Watersheds

The accounting of all forest management-related activities in the 30 Flathead basin watersheds is found in Appendix 2. Table 5 identifies those watersheds and displays the estimates of their surface disturbance made by SEQUOIA and of their water yield increases made by H2OY.

The correlation between the watersheds ranked from highest to lowest disturbance and highest to lowest water yield increases, evaluated with Pearson's R, was 0.88. This value is significant at the 95% confidence level and indicates the strong relationship observed between SEQUOIA and H2OY is not due to chance.

Table 5. Comparison of Modeling Results for 30 Watersheds in the Flathead Basin

WATERSHED		SEQUOIA (% of watershed as C.R.A.)	H2OY (% water yield increase)
1A	ELK CREEK	0.00	0.00
1B	ELK CREEK	0.00	0.00
2	GOAT CREEK	0.01	0.90
3	SQUEEZER	0.04	0.46
4	LION	0.00	0.00
5A	JIM	12.20	4.49
5B	JIM	13.00	4.26
6	PIPER	0.00	0.00
7	FREELAND	30.90	22.00
8	FISH	22.60	16.78
9	HAND	9.50	1.55
10	UPPER EF SWIFT	>0.00	N-A
11	SHEPPARD	15.70	10.24
12A	UPPER BIG	1.20	2.93
12B	LOWER BIG	3.00	3.32
13	LOWER COAL	4.30	1.58
14	COAL CREEK NF	6.70	3.03
15	COAL CREEK SF	3.90	1.70
17	RED MEADOW	3.40	1.83
18	WHALE	1.20	1.27
19	TRAIL	2.30	0.65
20	GRANITE	1.90	1.72
21	CHALLENGE	2.50	1.03
23	MORRISON	2.50	1.30
24A	HUNGRY HORSE	>0.00	0.60
24B	HUNGRY HORSE	>0.00	0.50
25	MARGARET	>0.00	1.64
26	TIGER	>0.00	0.11
27	EMERY	2.00	3.14
29	SQUAW TRIB	11.10	3.62

DISCUSSION

Howard Creek

The application of SEQUOIA to Howard Creek was to be a feasibility study, but actually exposed many problems facing coordinated watershed management in watersheds with mixed-ownership. For example, the watershed is 12636 acres (about 20

sq.mi.) and approximately 20% of the watershed has received silvicultural treatment during the past 10 years. That treatment figure is a little misleading in that the majority of timber harvest has been conducted on Industrial timber lands, which are only 50% of the watershed.

Even more revealing is that there are nearly 80 miles of system roads in the watershed, yet whole sections have not been entered. A 4 mile/sq.mi. road density may seem reasonable, but in areas of the watershed that have been entered and harvested, the actual road density is probably double that. Roads are the greatest source of sediment and influence the timing of runoff by effectively increasing the drainage density.

SEQUOIA estimates a 1989 CRA of about 1390 acres which is about 11% of the total watershed area. Again, activities have not been distributed across the entire watershed. If Howard Creek were on the Sequoia National Forest, the "flag would have been raised" because the watershed had reached the "threshold of concern." As previously stated, the Forest Service has its lands in the area under a harvest moratorium because concerns over cumulative watershed effects have been raised.

<u>Swan River Analysis Units</u>

Although SEQUOIA estimates that only 8.2% of the Swan River watershed is in cumulative runoff acreage, once again the disturbances are not uniformly distributed across the basin. Analysis unit #24, which has a CRA which is over 40% of its total

area and a road density of over 4 mi./sq.mi., probably has reached most peoples' TOC.

While 17 of 54 analysis units had CRA's greater than 10% of their areas, the median for disturbance was about 6.5%, and almost 25% of the Swan has seen less that 1% disturbance. Clearly, there is considerable room for additional forest management and timber harvest in the watershed. It may even be safe to assume that there are minimal cumulative watershed effects occurring basin-wide. This is supported, to some extent, by the Double Mass Analysis reported earlier in this document.

But it is also clear that perhaps 10 to 15% of the watershed has reached a level of disturbance that is too high. Perhaps there should be a coordinated effort to defer additional impacts in those areas and move to other areas of the drainage. If SEQUOIA's recovery estimates are correct, the deferral need only be for a decade or so in most cases.

The 30 Additional Watersheds

As expected, there was a very good correlation between the rankings of watershed disturbance as estimated by SEQUOIA and H2OY. However, only 3 of the watersheds had exceeded the water yield increase threshold employed by the Flathead National Forest. Six of the watersheds exceeded the 10% CRA threshold suggested by SEQUOIA. Both methods identified, in the same rank-order, Freeland, Fish and Sheppard Creeks as being above threshold. Interestingly, two of the SEQUOIA-threshold streams

were different reaches of Jim Creek. Jim Creek has been the center of recent concern over forest management impacts on fisheries and water quality.

There are a number of possible reasons why the two methods don't have perfect agreement. Foremost are that they measure different types of disturbance and have vastly different estimates of disturbance recovery. Nevertheless, the strong agreement between the methods suggest that they are telling the same story. The question still remains as to when in the story we get concerned about the outcome.

Thresholds are a concept in need of study. Does a 10% increase in water yield or a 10% CRA mean anything? Fortunately, the results of this study will be compared and correlated with the other studies funded by the Flathead Cooperative, and together may help build an understanding of cumulative watershed effects in the Flathead Basin.

<u>Comments and Observations</u>

The application of Sequoia to the Flathead Basin was generally uneventful. We found it to be a straight-forward accounting system. However, if the procedure is to be adopted for routine use, a few general comments regarding data collection and organization may be helpful.

SEQUOIA is structured to account for forest management activities that take place over a ten year period. With the exception of roads, no older activities are considered. In watersheds with mixed-ownership, relevant data must be obtained

from the various land owners. This was perhaps the most difficult part of the application.

Plum Creek Timber Company maintained the best-organized and most easily accessible records. The harvesting, site preparation and road building were organized and cross referenced by year and by township, range and section. The information was easy to understand and interpret. It also appeared to be the most complete and didn't require consultation with other sources.

The Montana Department of State Lands maintained records that were easily accessible and the personnel at the DSL were very helpful in locating the information needed. However, a small amount of the information was incomplete, and additional sources were needed to interpret or fill in the missing timber harvest information.

The U.S. Forest Service data were the most difficult to access and interpret. The Forest Service uses map overlays with management codes indicating the history of activity at a given location. The code number on the overlay must then looked up in code book to determine specific dates and activities. This system may work well for people familiar with it, but it proved very time-consuming and frustrating for the un-initiated. Further, some information on the overlays dated back thirty years, whereas Plum Creek Timber Company and Department of State Lands information could be easily sorted and identified by individual year. If this procedure is to be used by others in

the future, users should become familiar will the Forest Service system before attempting to interpret and process the data.

The areal extent of site preparation and road disturbance - both required parts of SEQUOIA's accounting method - could not always be determined from the records. This did not cause a large problem with data interpretation, however, and assumptions were made with both activities.

Total areas receiving site preparation were assumed to total areas of harvest activity. We know this is not always the case. The type of site preparation, such as mechanical or burning, was provided in most instances, but when information was missing, we assumed that mechanical site preparation was employed. Road classification (eg. system roads, abandoned roads, or ORV trails) was sometimes difficult to determine from the records. To simplify the problem, roads within the harvest areas were considered abandoned roads unless they were <u>obviously</u> system roads. All connecting roads between harvest units were considered system roads. This likely produced an underestimate of total road disturbance, but it was consistently used in the study.

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LITERATURE CITED

Brown III, William M., Walter G. Hines, David A. Rickert, and Gary L. Beach, 1979. A Synoptic approach for analyzing erosion as a guide to land use planning. U.S. Geological Survey Circular 715-L. U.S. Geological Survey; Reston, Virginia

Cline, R.J., G. Cole, W. Megahan, R. Patten, J. Potyondy 1981. Guide for predicting sediment yields from forested watersheds. USDA Forest Service, Northern Region, Missoula, MT. 48 p.

Cobourn, John., 1989a. An Application of cumulative watershed effects (CWE) analysis on the Eldorado National Forest in California. IN: AWRA Symposium Proceedings on Headwaters Hydrology, Missoula, Montana. pp. 449-461.

Cobourn, John., 1989b. Is cumulative watershed effects analysis coming of age? J. Soil and Water Cons. 44(4): 267-70

Council on Environmental Quality (CEQ). 1978. CEQ's NEPA Regulations. 40 CFR; sections 1500-1508. Washington D.C.

Environmental Protection Agency (EPA). 1980. An approach to water resources evaluation of non-point silvicultural sources (a procedural handbook) EPA-600/8-80-012. Athens, GA. 861 p.

Grant, G.E. 1986. An assessment technique for evaluating off-site effects of timber harvest activities on stream channels. IN: Papers presented at American Geophysical Union Meeting on Cumulative Effects, N.C.A.S.I. Tech. Bull. 490., New York.

Grant, G.E. 1988. The RAPID technique: A new method for evaluating downstream effects of forest practices on riparian zones. USDA Forest Service, Pacific Northwest Research Station; General Technical Report PNW-GTR-220; Portland, OR. 36 p.

Goldstein, R.A., Mankin, J.B., Luxmore, R.J. 1974. Documentation of PROSPER: a model of atmosphere-soil-plant water flow. Environmental Sci. Div. Publication No. 579; Oak Ridge Natl. Lab., Oak Ridge, TN. 75 p.

Harr, R. Dennis, Fredriksen, R.L., Rothacher, J. 1975. Changes in hydrographs after road building and clearcutting in the Oregon Coast Range. Water Resour. Res. 11(3):436-444

Harr, R.D. 1981., Some characteristics and consequences of snowmelt during rainfall in western oregon. J. Hydrol. 53: 277-304.

Haskins, D.M. 1986. A management model for evaluating cumulative watershed effects. In: Papers presented at California Watershed Management Conference, Nov. 18-20. West Sacramento, CA. p. 125-130.

Hauer, F.R. 1990. An analysis of the effect of timber harvest on streamflow quantity and regime: an examination of historical records. Open file Report 112-90. Flathead Lake Biological Station, University of Montana, Polson, MT. 43 p.

Hogan, D.L. and D.J. Wilford 1989. A sediment transfer hazard classification system: linking erosion to fish habitat. IN: Proceedings Watershed 89 - A conference on the stewardship of soil, air, and water resources., Juneau, AK. USDA Forest Service, Alaska Region, R10-MB-77. pp. 143-155.

King, J.G. 1989. Streamflow responses to road building and harvesting: a comparison with the equivalent clearcut area procedure. Intermountain Research Station. Res. Pap. INT-401.

Klock, G.A. 1984. Modeling the cumulative effects of forest practices on downstream aquatic ecosystems. J. Soil and Water Cons. 40(2):237-241.

Leaf, C.F. and G.E. Brink 1975. Hydrologic simulation model of Colorado subalpine forest. USDA Forest Service, Rocky Mt. Forest and Range Exp. Station, Res. Paper RM-107. Fort Collins, CO. 23 p.

Leopold, L.B., Clarke, F.E, Hanshaw, B.B, Balsley, J.R., 1971. A procedure for evaluating environmental impact. USGS Circ. 645. pp. 295-307.

Lull, K.J. 1990. A G.I.S. application for assessment of nonpoint source pollution risk on managed forest lands. Unpub. MS Thesis. University of Montana, School of Forestry. 92 p.

McCorison, M.F., Johnejack G., Kissinger E., 1989. A method to analyze watershed sensitivity. IN: Proceedings Watershed 89 - A conference on the stewardship of soil, air, and water resources., Juneau, Alaska, March 21-23, Alexander, E.B., Editor., USDA, For. Serv. Alaska Region, R10-MB-77. pp. 157-164.

Montana Cumulative Watershed Effects Cooperative (MCEC) 1988. Process to address watershed effects in mixed ownership drainages. MT Dept. of State Lands, Office of State Forester. Missoula, MT 5 p.

Musgrave, G.W., 1947, The quantitative evaluation of factors in water erosion, A first approximation: Jour. Soil and Water Conserv., 2(3): 133-138.

Potts, Donald F. 1984. The hydrologic impacts of a large-scale mountain pine beetle (<u>Dendroctonus ponderosae</u> Hopkins) epidemic. Water Resources Bulletin 20(3):373-377.

Rice, R.M. 1982. A perspective on the cumulative effects of logging on streamflow and sedimentation. Proceedings, Edgebrook conference; July 2-3; Berkeley, CA. Spec. Pub. 3268. Univ. Calif. Div. Agric. Sci. 36-46 p.

Rickert, D.A.; Hines, W.G.,; McKenzie, S.W., 1975. Methods and data requirements for river-quality assessment: Water Res. Bull. 11(5):1013-1039.

Rickert, D.A., G.L. Beach, J.E. Jackson, D.M. Anderson, H.H. Hazen and E Suwijn. 1979. Oregon's procedure for assessing the impacts of land management activities on erosion related nonpoint source problems. Oregon 208 Nonpoint Source Project, Oregon Dept. of Env. Quality, Portland, OR.

Searcy, J.K. and C.H. Hardison 1960. Double Mass Curves: Manual of Hydrology: Part 1. General Surface-Water Techniques. U.S. Geological Survey Water-Supply Paper 1541-B, 66pp.

USDA Forest Service. 1974. Forest Hydrology: Hydrologic effects of vegetation manipulation. Northern Region, Missoula, MT 201 p.

USDA Forest Service. 1977. A computer model for determining water yield from forest activities. Idaho Panhandle National Forests, Coeur d'Alene, ID 36p.

USDA Forest Service. 1981. A method to assess and predict cumulative watershed effects. Sequoia National Forest. Porterville, CA 21 p.

USDA Forest Service. 1988. Region 5 Soil and Water Conservation Handbook (FSH 2509.22) "Cumulative Off -site Watershed Effects Analysis". San Francisco, CA.

PLEASE NOTE!

APPENDICES 1 AND 2

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